An Updated Analysis of GNSS RO Lower Troposphere Refractivity Bias

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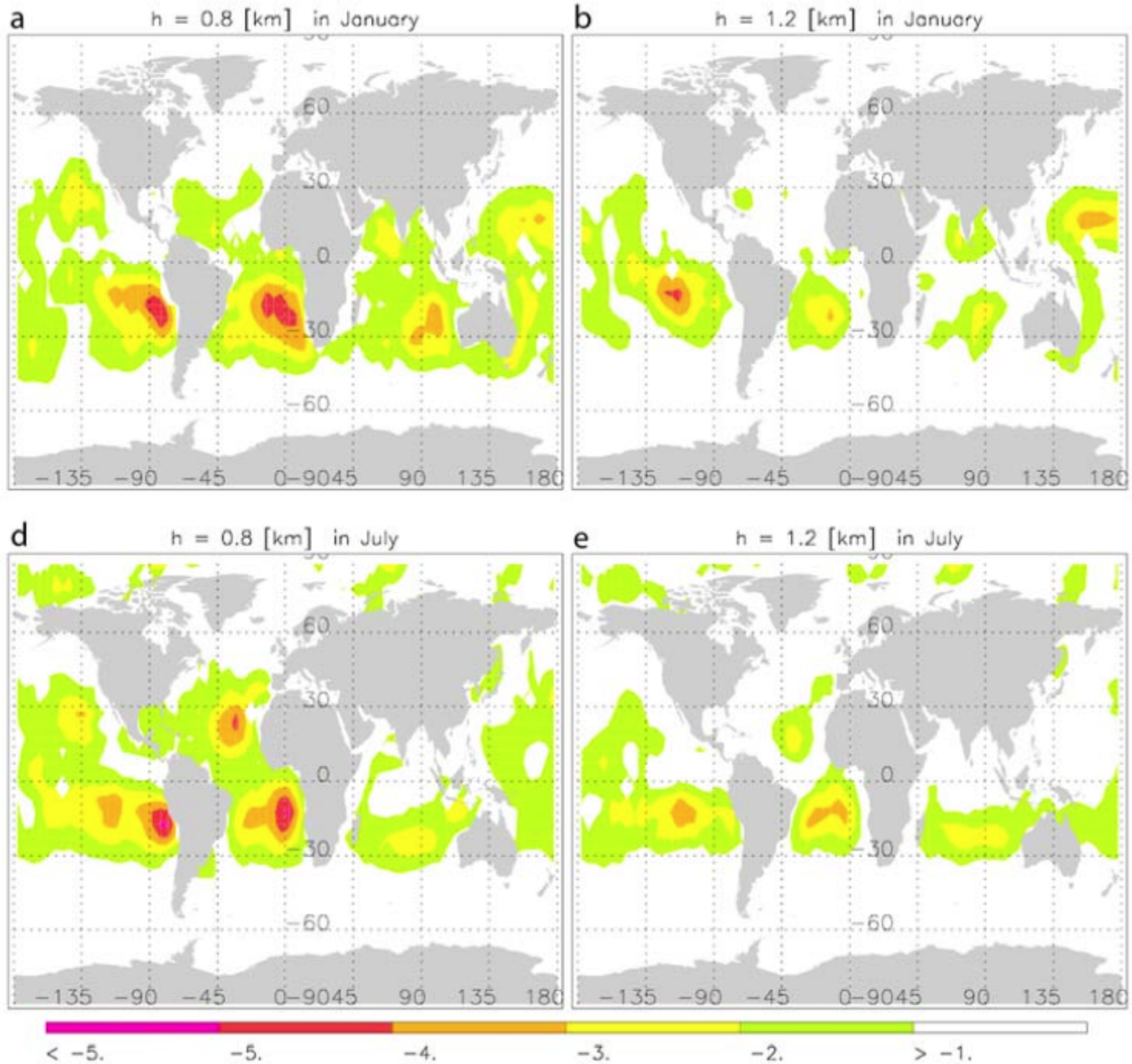
Outline

1. Negative bias in the lower troposphere
   – Recap
   – Case studies over Southeast Pacific
2. Accuracy vs. vertical resolution
   – Radioholographic (RH) retrieval vs. traditional approach

Background

1. RO retrieval: time series of received signal **amplitude & phase** is converted to **bending angle vs. impact parameter** which is then integrated via Abel inversion to give **refractivity** (*N*) profile.
2. Impact altitude ≈ altitude+2 km near the surface.
3. 3% refractivity error ≈ 10% spec humidity in tropical lower troposphere.

Fractional Refractivity difference (RO-ECMWF) [%]



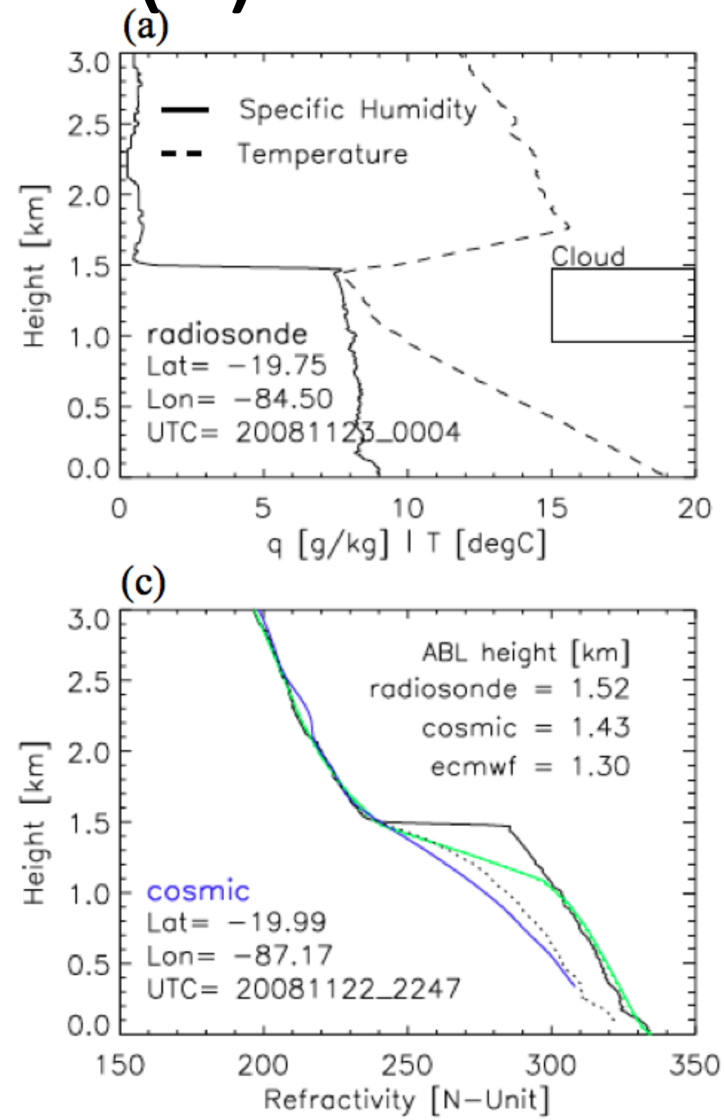
Xie et al. GRL, 2010

Negative N-Bias (1)

- RO refractivity has been shown to be systematically smaller than the global weather analyses and other collocated measurements < 2 km in the tropics.
- It is understood theoretically that a negative bias will be present below refractivity layer with vertical gradient exceeding some critical threshold (dN/dz < -157 per km).
  - This is due to the breakdown of non-uniqueness between bending and refractivity. There exists infinite number of refractivity solutions for the same bending. Abel inversion always picks the smallest (dN/dz > -157).

Negative N-Bias (2)

- CR layers are often associated with sharp inversion layers capping the planetary boundary layer. The strongest CR layers occur in the subtropical Eastern oceans.
- How will horizontal variability affect its impact?
- **Can the observed bias be fully explained by CR?**



Xie et al. ACP, 2012

Horizontal extent of CR

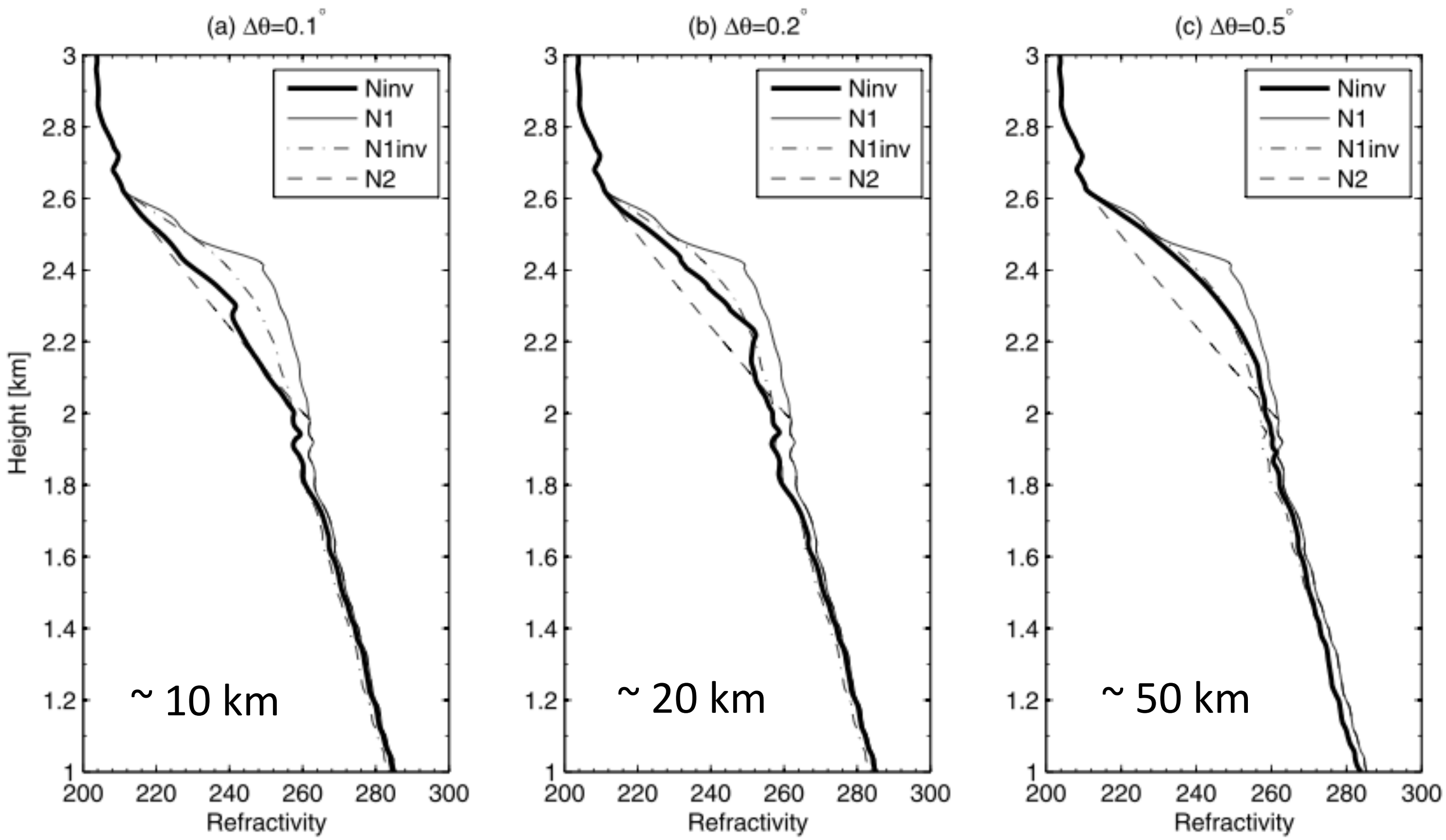
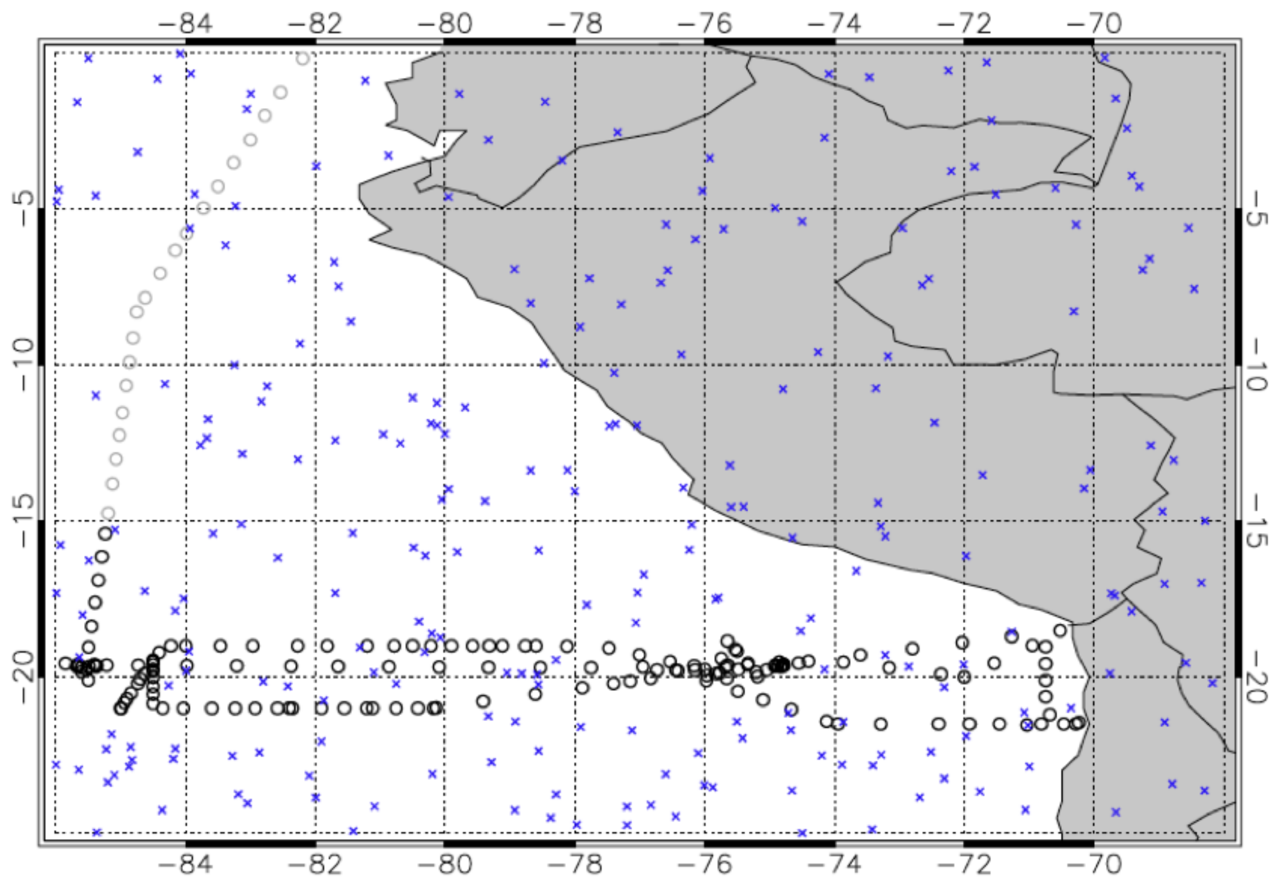


Figure 11. Simple 2-D example showing the effect of horizontal inhomogeneity on GPS RO retrievals. The profile $N_1(r)$ has a duct with width of 183 m and is confined to an angular extent of $\pm\Delta\theta$ around the tangent point. Outside this region, $N_1(r)$ transitions smoothly to a background profile $N_2(r)$ which has no duct. The plot shows that the inverted profile $N^{(inv)}(r)$ becomes closer to the inverted profile $N_1^{(inv)}(r)$ (obtained when $N_1(r)$ is globally spherically symmetric) as $\Delta\theta$ increases.

Ao, Radio Sci., 2007

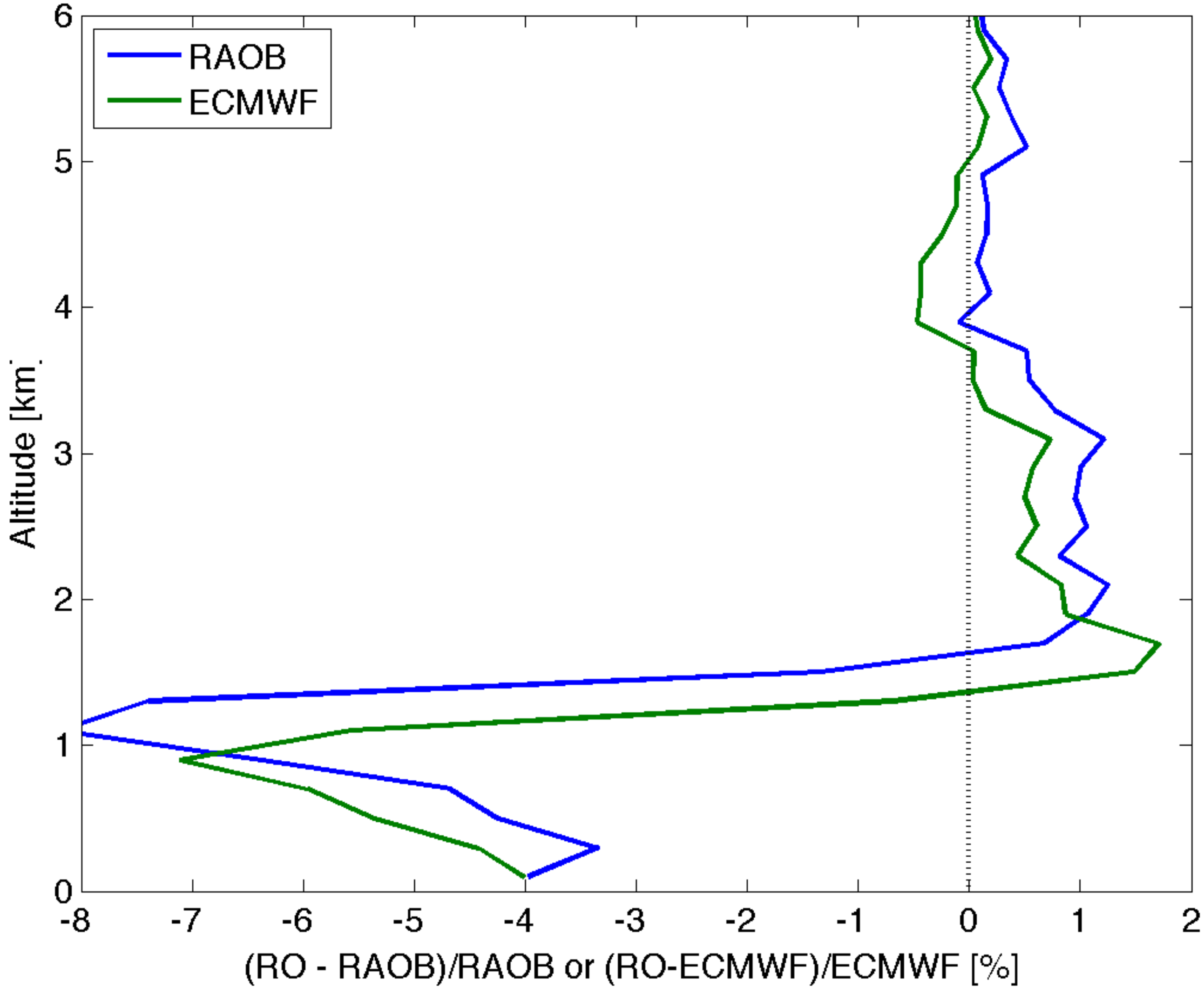
Case Studies over SE Pacific



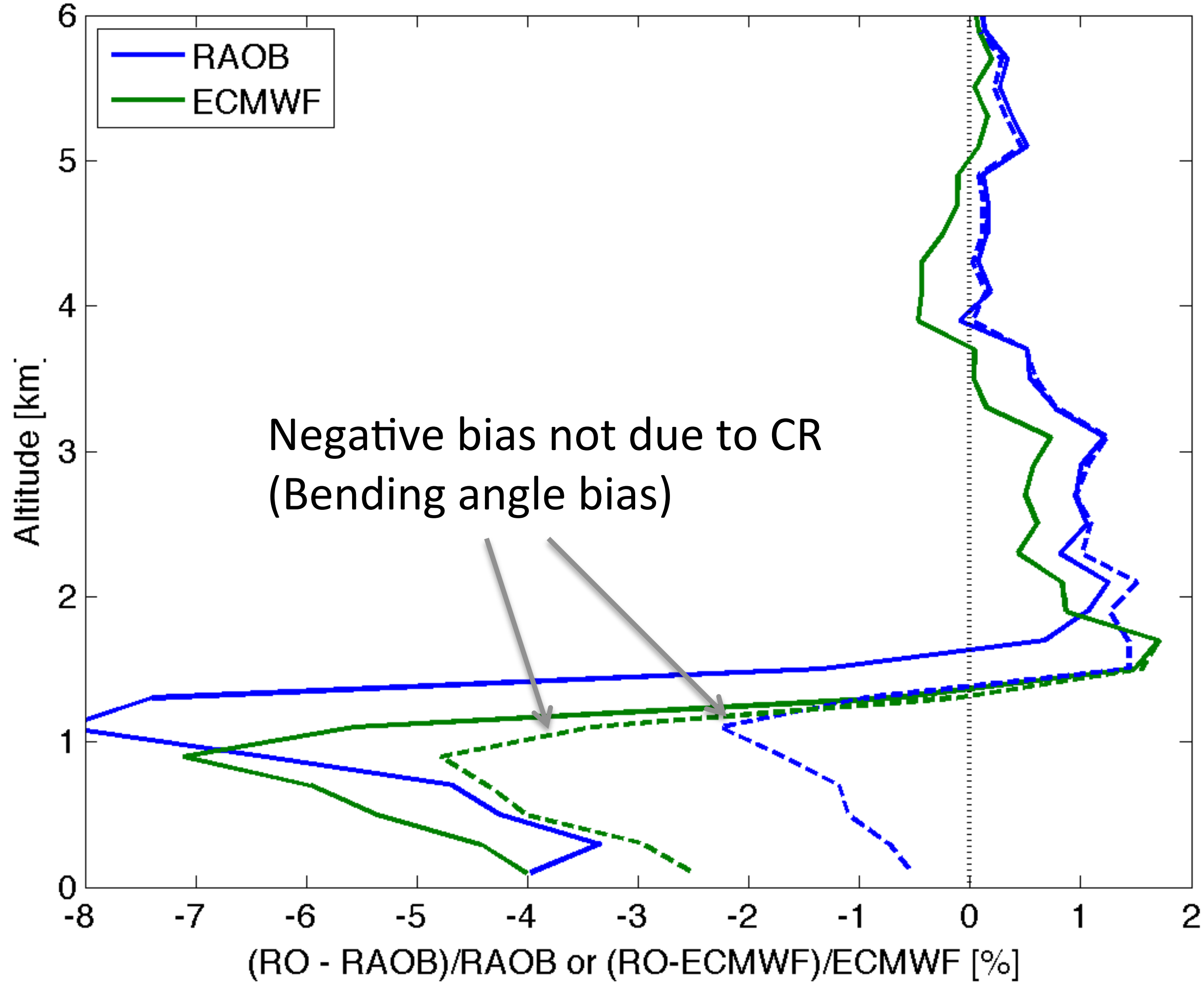
Xie et al. ACP, 2012

Fig. 1. Map of the ship-borne radiosonde (circle) and COSMIC RO (cross) sounding locations during VOCALS-REx field campaign from 20 October to 1 December 2008.

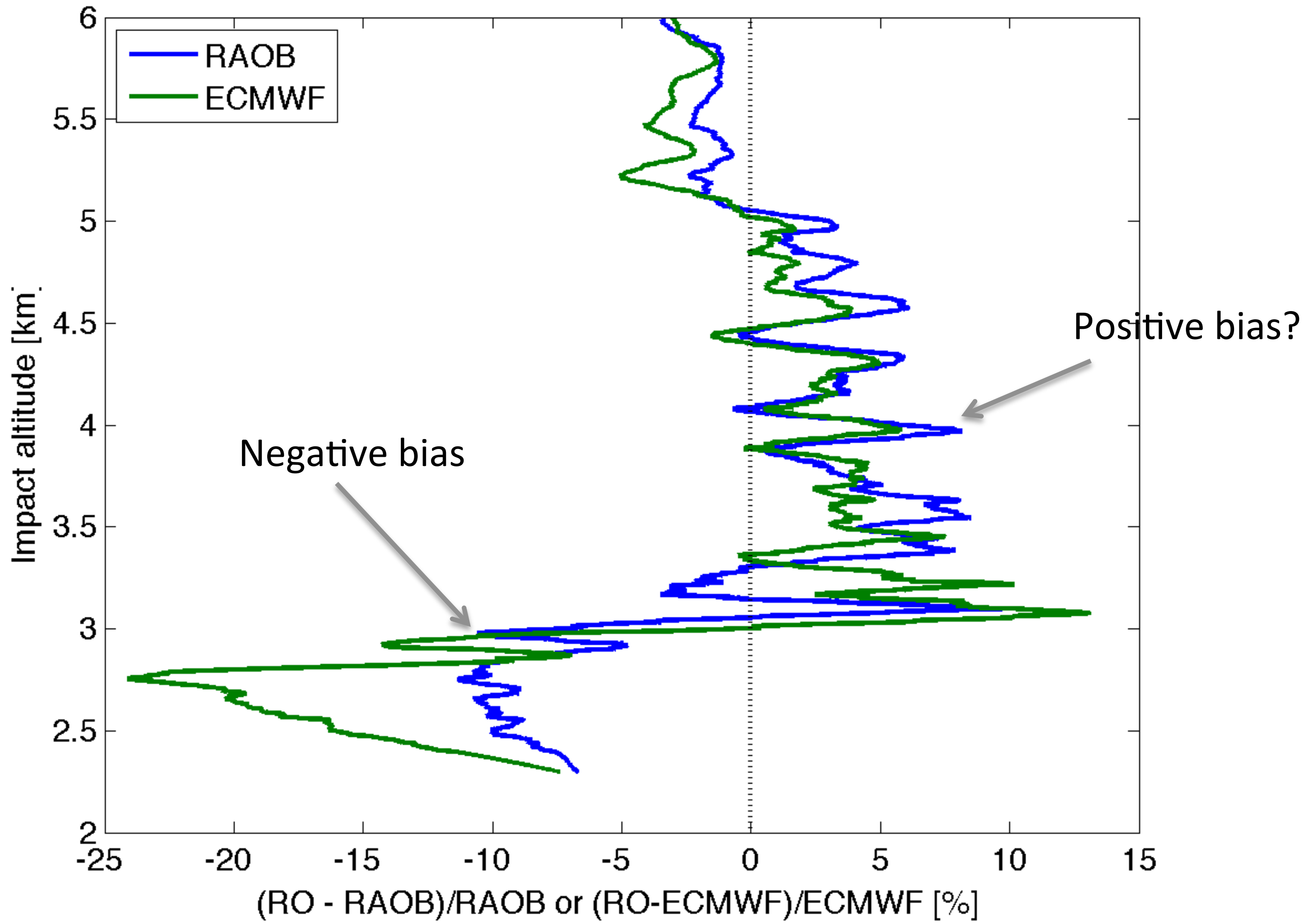
Refractivity Difference (18 matches)

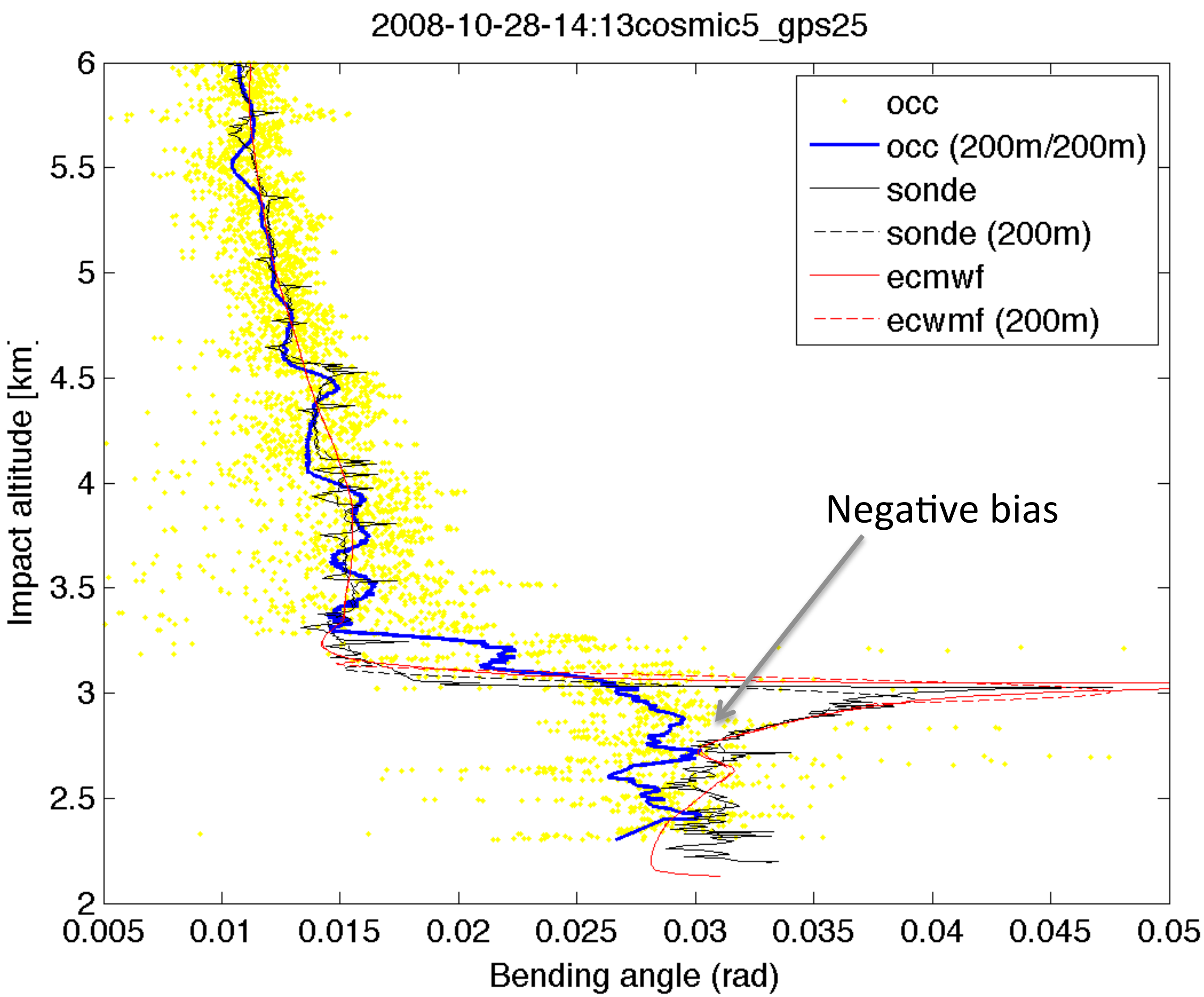


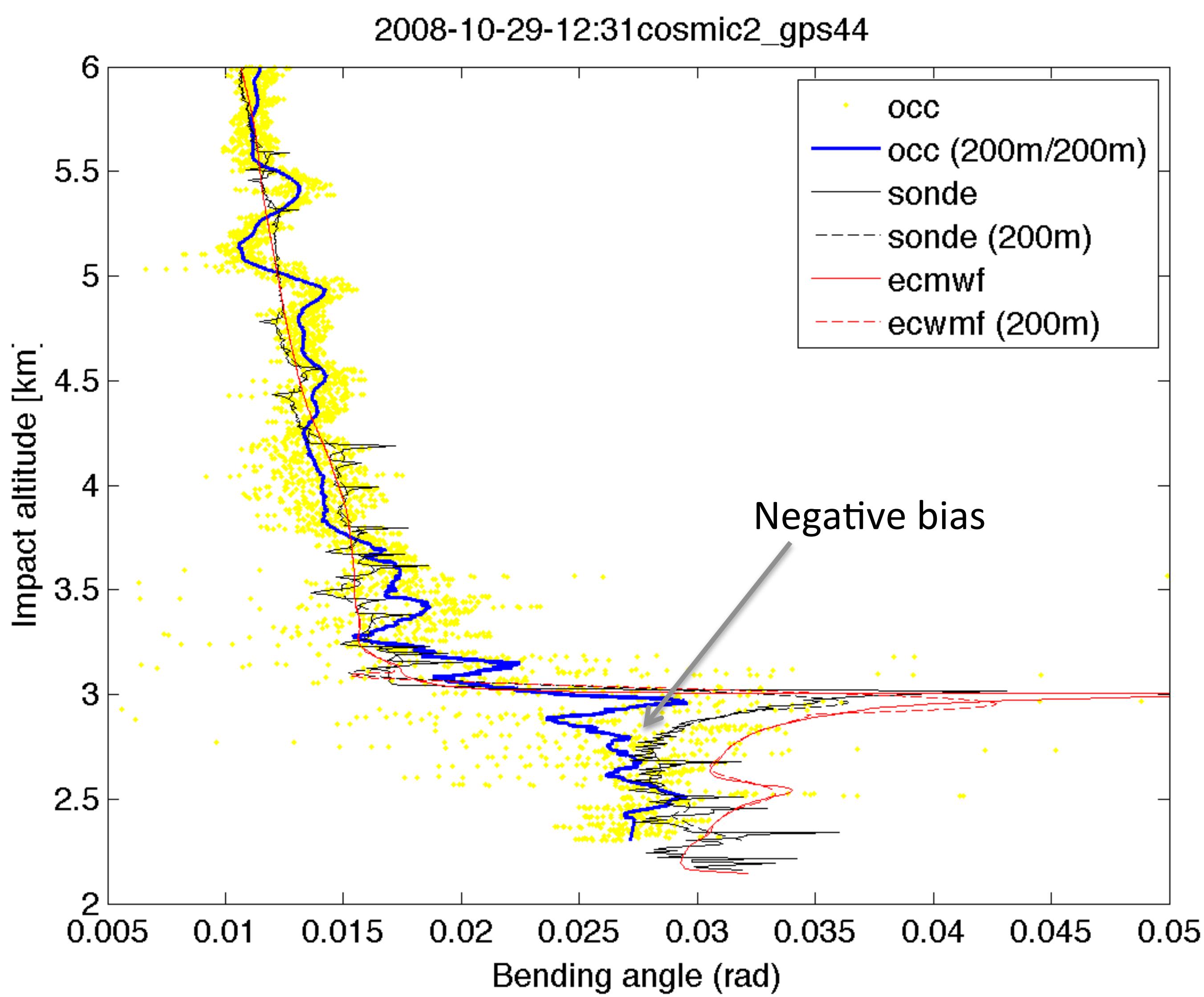
Difference Relative to Abel-N



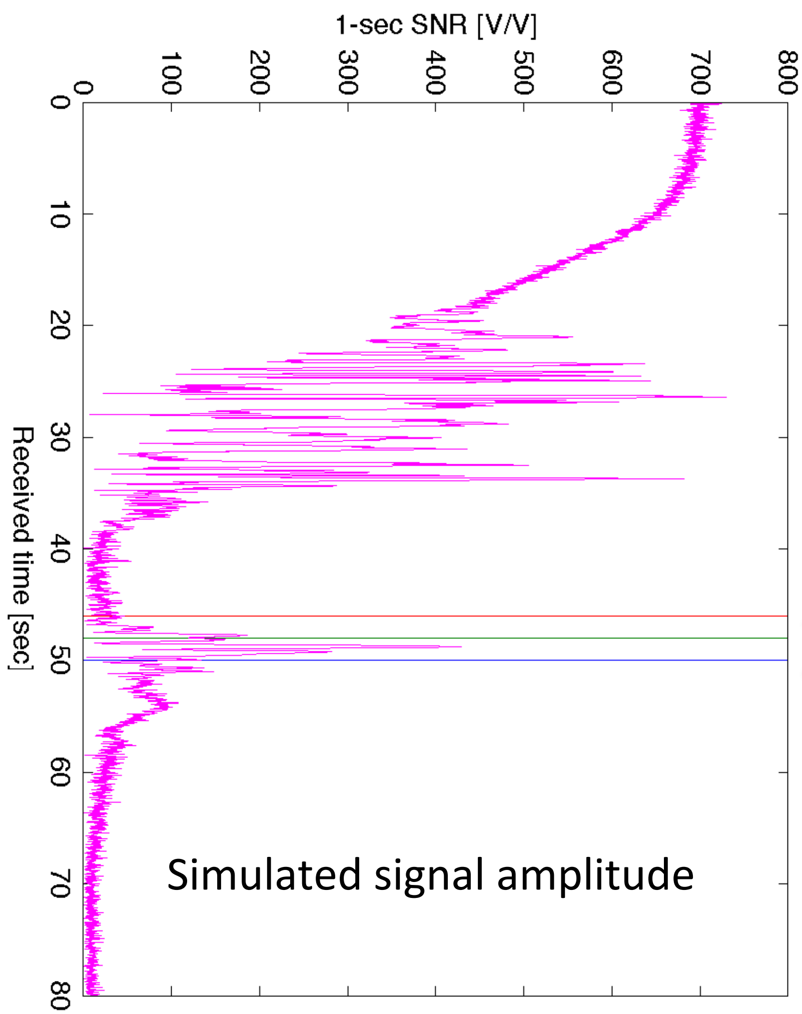
Bending Angle Bias



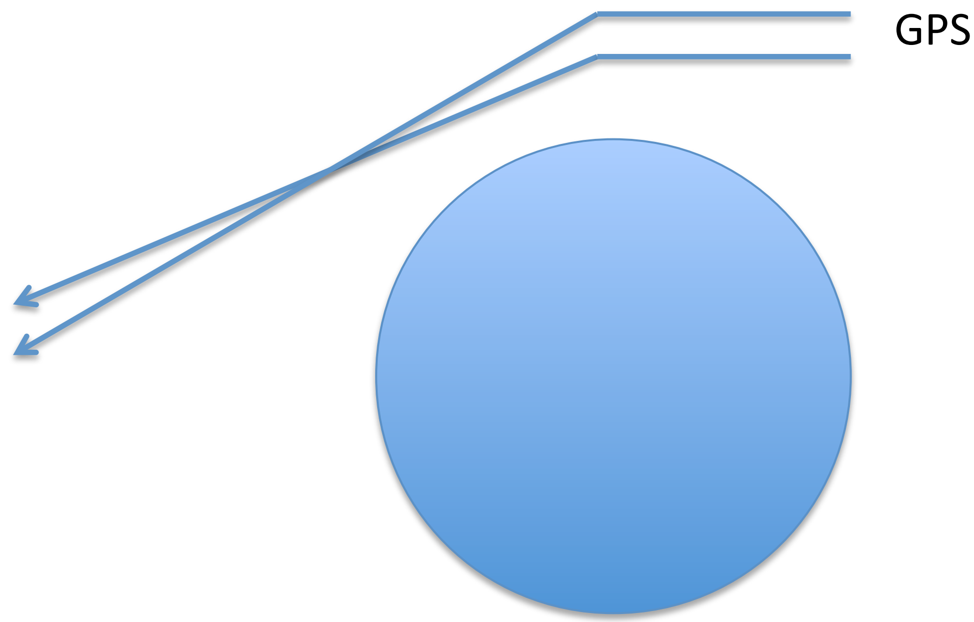

2008-10-28-14:13cosmic5_gps25
Impact altitude [km]
Bending angle (rad)
6
5.5
5
4.5
4
3.5
3
2.5
2
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
occ
occ (200m/200m)
sonde
sonde (200m)
ecmwf
ecwmf (200m)
Negative bias


2008-10-29-12:31cosmic2_gps44
occ
occ (200m/200m)
sonde
sonde (200m)
ecmwf
ecwmf (200m)
Negative bias
Impact altitude [km]
Bending angle (rad)
6
5.5
5
4.5
4
3.5
3
2.5
2
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05

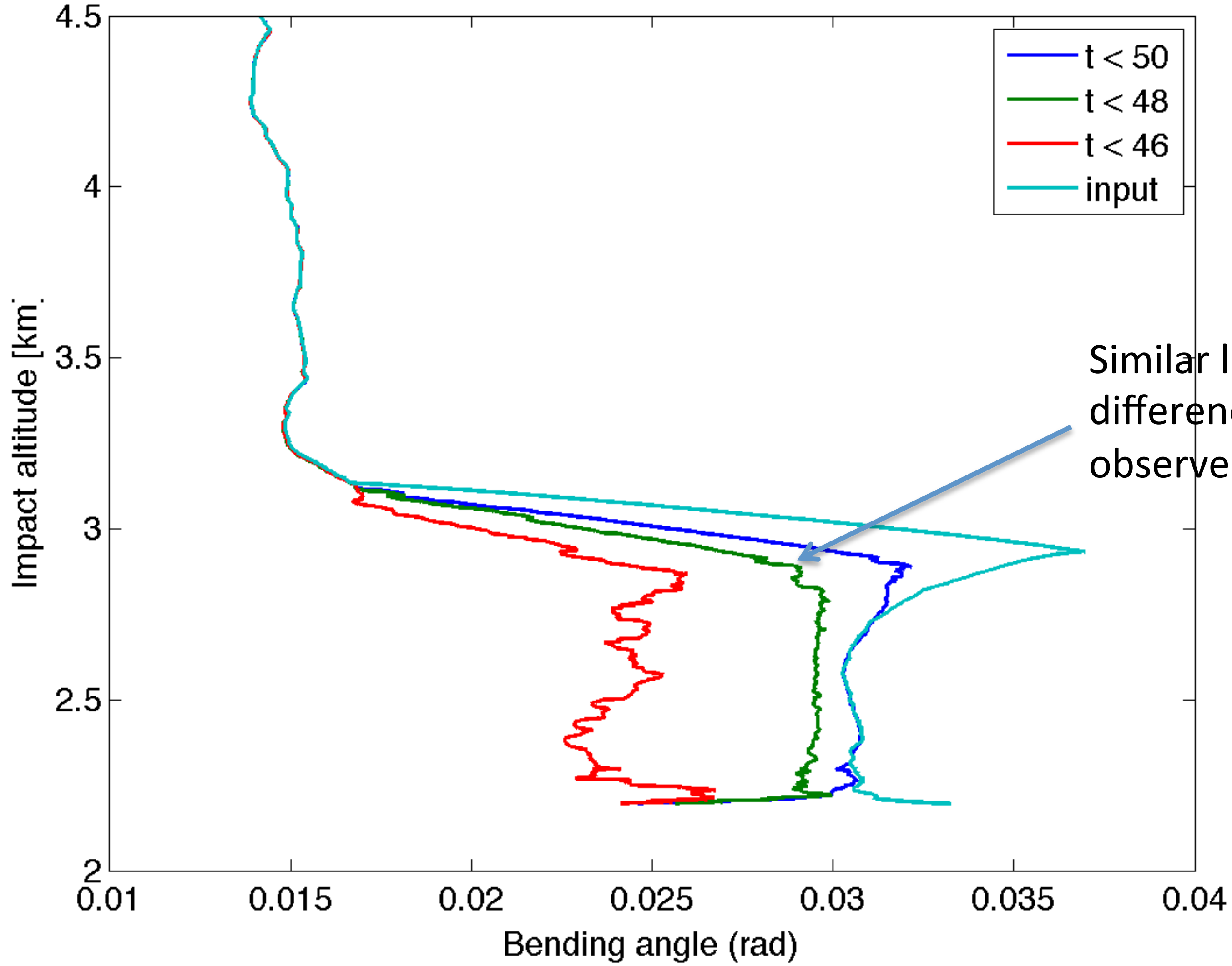
The observed negative bending angle bias suggests that data in low line-of-sight altitudes (LSA) are either not recorded or significantly degraded.



Rays with large bending arrive at lower LSA.

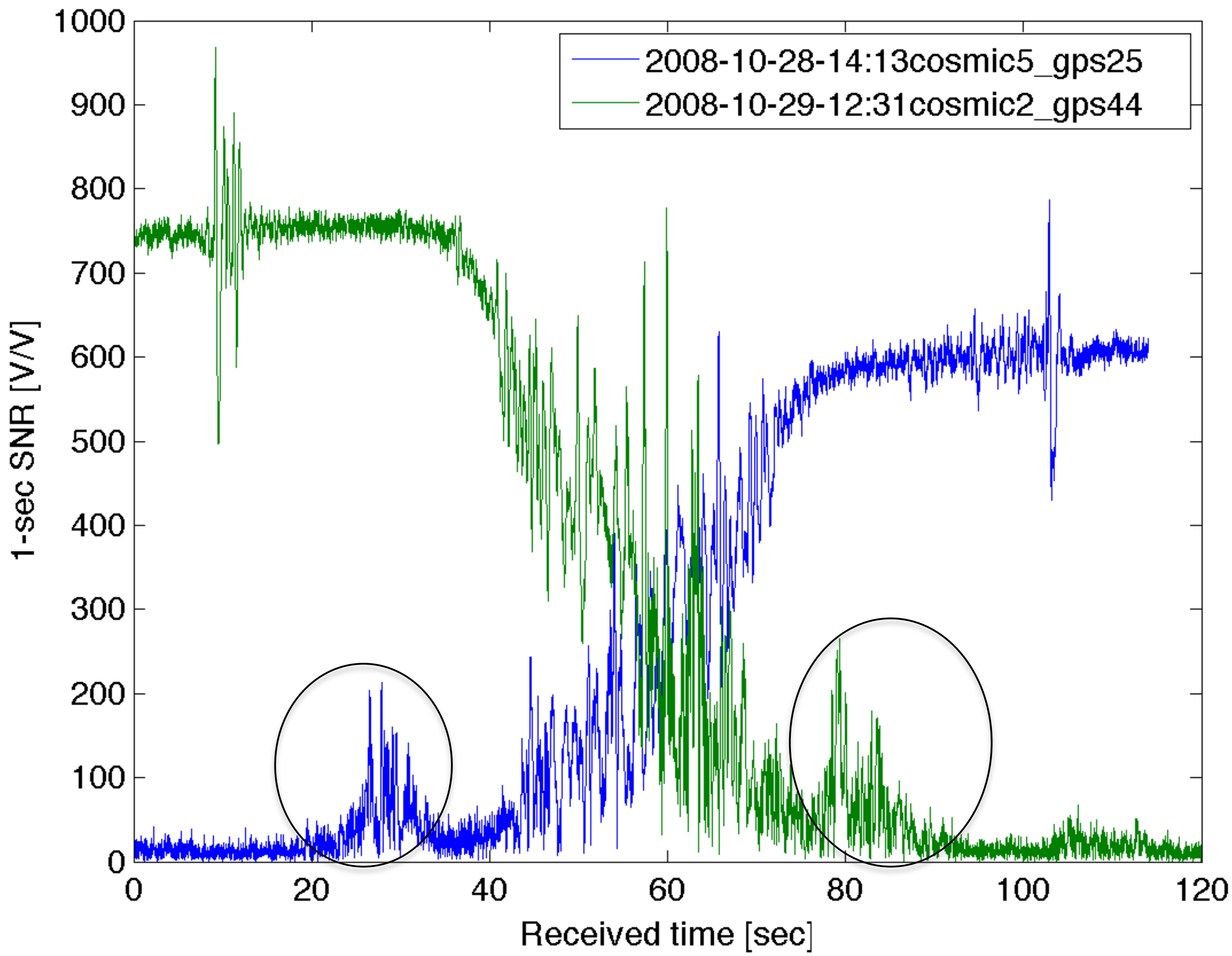


Simulated Bending with Truncations

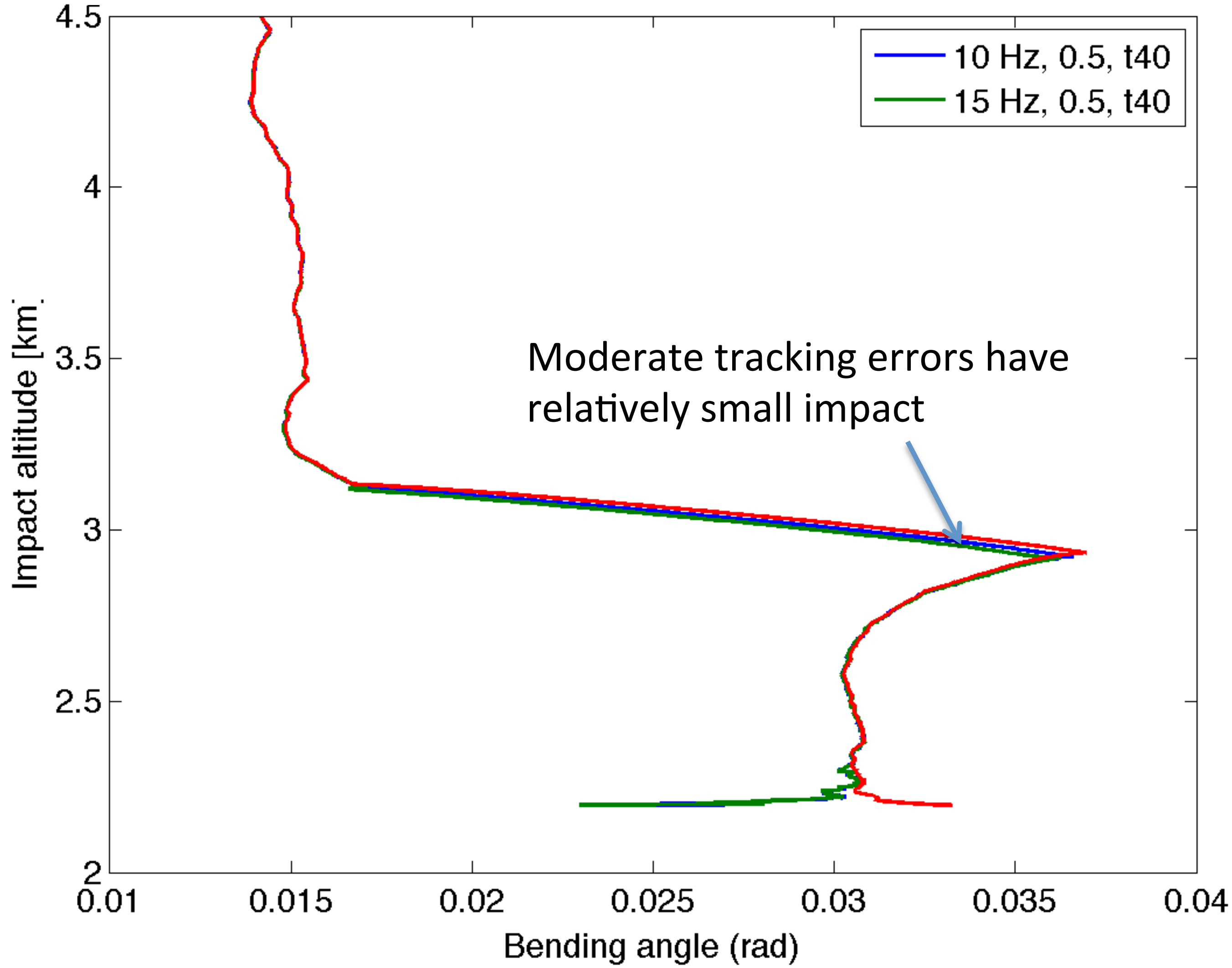


Similar level of difference as observed

However, actual measurements show continuous tracking with seemingly sufficient SNRs at low LSAs.



Simulated Bending with Tracking Errors



Summary

- This study confirms that part of the negative refractivity bias is due to a negative bias in the bending angle.
- The bending angle bias is likely due to degradation of the signal in the “tail end” (low LSA) of the measurement; however, simulations with moderate tracking errors could not reproduce the same level of errors.

Ongoing/Future Work

- Continue simulation study of N-bias.
- CHAMP & COSMIC geopotential height from comparisons with CMIP5.
- Tropical belt diagnostics via tropopause height distribution from over 10 years of RO data.